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UNITED STATES PATENT APPLICATION

FOR

HEAT PIPE INCLUDING ENHANCED NUCLEATE BOILING SURFACE

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HEAT PIPE INCLUDING ENHANCED NUCLEATE BOILING SURFACE

BACKGROUND

[0001] The claimed invention relates to heat pipes and, more particularly, to heat pipes for dissipating heat generated by integrated circuits.

[0002] Various heat pipes have been used to dissipate heat generated by integrated circuits, for example within personal computers, mobile computers, or similar electrical devices. Heat pipes may include an evaporator section and a condenser section. Heat may be transferred from the evaporator section to the condenser section by boiling a liquid at the evaporator section.

[0003] Heat pipes may also include a wick between the evaporator section to the condenser section to act as a pump to bring liquid back from the condenser section to the evaporator section. The wick and liquid may also extend over the integrated circuit in the evaporator section of the heat pipe. The thermal conductivity of the wick-liquid mixture in the evaporator section, however, may be somewhat low, causing a somewhat high thermal resistance to heat transfer in such a heat pipe.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate one or more implementations consistent with the principles of the invention and, together with the description, explain such implementations. In the drawings,

[0005] Fig. 1 is an internal top view of an example implementation of a heat pipe consistent with the principles of the invention;

[0006] Fig. 2 is a side view of the heat pipe of Fig. 1 in an implementation consistent with the principles of the invention;

[0007] Fig. 3 is a side view of the heat pipe of Fig. 1 in another implementation consistent with the principles of the invention; and

[0008] Fig. 4 is an end view of the heat pipe of Fig. 3 in an implementation consistent with the principles of the invention.

DETAILED DESCRIPTION

[0009] The following detailed description refers to the accompanying drawings. The same reference numbers may be used in different drawings to identify the same or similar elements. Also, the following detailed description illustrates certain implementations and principles, but the scope of the claimed invention is defined by the appended claims and equivalents.

[0010] Fig. 1 is an internal top view of an example implementation of a heat pipe 100 consistent with the principles of the invention. Heat pipe 100 may be located in a desktop or mobile computer proximate to an integrated circuit chip (not shown), such as a processor, that produces heat. Heat pipe 100 may include outer walls 110, a wick 120, and a boiling structure 130. Although not explicitly illustrated in Fig. 1, heat pipe 100 may also include a liquid coolant.

[0011] An evaporator portion of heat pipe 100 may be located near boiling structure 130, and a condenser portion of heat pipe 100 may be spaced apart from boiling structure 130 (e.g., including the far end of heat pipe 100). The overall length of heat pipe 100 may be in a range of about 45 mm to about 300 mm. The overall diameter of heat pipe 100 may be in a range of about 2 mm to about 30 mm.

[0012] Outer walls 110 may enclose both wick 120 and boiling structure 130, as well as the coolant. Outer walls 110 may contact the integrated circuit chip, and they may include a highly thermally conductive material, such as copper or another metal. Because Fig. 1 is an internal top view, the top one of outer walls 110 is not illustrated, and the bottom one of outer walls 110 is hidden by wick 120 and boiling structure 130. Outer walls 110 may be formed in a roughly rectangular shape, as illustrated in Fig. 1, or any other geometry that facilitates access to boiling structure 130 by the coolant. Outer walls 110 may also be formed to prevent the escape of vapor or liquid.

[0013] Wick 120 may include a porous material (e.g., sintered spherical copper particles, sintered metal powder, a fiber material, and/or a screen material) that covers a bottom surface of heat pipe 100, except for the area occupied by boiling structure 130. The porous material of wick 120 may include particles that have an average diameter in a range from about 2 μm to about 150 μm. This average diameter may be referred to as the mean feature size (or pore size) of wick 120. The porous material of wick 120 may be formed on the lower surface of heat pipe 100 with an average thickness in a range from about 1 mm to about 2.5 mm. Wick 120 may, by virtue of its porous structure, bring coolant from the condenser portion of heat pipe 100 to the evaporator portion at or near boiling structure 130. In this manner, wick 120 may act to hydrate boiling structure 130.

[0014] In other implementations, wick 120 may include axial grooves that act to bring coolant from the condenser portion of heat pipe 100 to the evaporator portion at or near boiling structure 130. Other types of homogenous structures for wick 120 may include an open annular structure, an open artery structure, and/or an integral artery structure. In still other implementations consistent with the principles of the invention, various composite structures may be used for

wick 120 that may include one or more of the homogeneous structures noted above (e.g., sintered particles, screen, fibers, grooves, etc.). Wick 120 may be designed to have a relatively high capillary pumping efficiency to hydrate boiling structure 130.

[0015] Boiling structure 130 may include a porous material (e.g., spherical metal particles of various sizes sintered onto the bottom outer wall 110) that roughly corresponds in area and orientation to a top surface of the integrated circuit chip to be cooled. Boiling structure 130 typically may be rectangular or square with an area in a range from about 0.25 cm^2 to about 10 cm^2. The porous material of boiling structure 130 may include, for example, copper particles that have an average diameter in a range from about 50 μm to about 500 μm, which may be greater than the average particle size of wick 120. In some implementations, the average diameter of the particles in boiling structure 130 may be around 300 μm. This average diameter may be referred to as the mean feature size of boiling structure 130. The porous material of boiling structure 130 may also be formed on the lower surface of heat pipe 100 with an average thickness in a range from about 0.5 mm to about 2 mm, which may be less than or equal to the average thickness of wick 120.

[0016] Boiling structure 130, by virtue of its geometry and material, may have a relatively low thermal resistance. For example, an average diameter of about 300 μm, boiling structure 130 may accomplish boiling with only 1-3 °C superheat (at 10-50 W/cm^2 heat flux). Such low overheat may result in a thermal resistance of about 0.03-0.1 °C/W resistance for a 1 cm^2 heat source (e.g., a thermal resistivity of 0.03-0.1 °C-cm^2/W). Because of boiling structure 130's low thermal resistance, the material of wick 120 may have a somewhat higher thermal resistivity (e.g., 0.2 °C-cm^2/W or greater) without adversely affecting the heat transfer efficiency of heat pipe 100. Similarly, wick 120 may be designed to have more effective capillary pumping than boiling structure 130.

[0017] Heat pipe 100 may have a roughly rectangular cross-sectional shape, or a roughly circular cross-sectional shape. Fig. 2 is a side view of heat pipe 100 with a roughly rectangular cross-sectional shape in an implementation consistent with the principles of the invention. In addition to elements 110-130 discussed above with regard to Fig. 1, heat pipe 100 may also include a coolant 210 and a vapor space 220.

[0018] Coolant 210 may include water, methanol, ethanol, acetone, heptane, Freon, or another refrigerant. Coolant 210 may pool on boiling surface, as illustrated in Fig. 2, and may also permeate wick 120. Although primarily liquid, some coolant 210 may be converted to a vapor by boiling over boiling structure 130.

[0019] One way to ensure continuous wetting of boiling structure 130 by coolant 210 may be to arrange wick 120 to extend vertically above boiling structure 130 on all sides, as illustrated in Fig. 2. For example, wick 120 may extend from about 0.1 mm to about 1 mm above boiling structure 130 to define a cavity. Wick 120 may feed coolant 210 into this cavity from all sides (see Fig. 1) to form a pool of coolant 210 on boiling structure 130. In such an implementation, coolant 210 may or may not also collect above wick 120, perhaps depending on how much of coolant 210 is currently in vapor form.

[0020] In another implementation, wick 120 may not extend vertically above boiling structure 130. In such an implementation, however, the amount of coolant 210 should be sufficient to ensure pooling on at least boiling structure 130. In this manner, boiling structure 130 may remain continuously wetted by coolant 210.

[0021] Vapor space 220 may be located between wick 120 and the top one of outer walls 110. Vapor-phase coolant 210 may be transported to the condenser portion of peat pipe 100 via vapor space 220 (and possibly also wick 120), where it cools, becomes liquid, and is transported back

to boiling structure 130 by wick 120. In some implementations consistent with the principles of the invention, vapor space may have a height in a range from about 0.5 mm to about 2 mm, although other heights are possible.

[0022] Figs. 3 and 4 are views of heat pipe 100 with a roughly circular cross-sectional shape in another implementation consistent with the principles of the invention. In addition to elements 110-130 and coolant 210 discussed above with regard to Figs. 1 and 2, heat pipe 100 in Fig. 3 may include a wick 310 extending around an inner circumference of heat pipe 100. As illustrated in Fig. 4, vapor space 220 may also have a roughly circular cross-section.

[0023] As described above with regard to Fig. 2, wick 310 may include a wrapped screen structure, a sintered metal structure, a fiber structure, and/or an axially grooved structure. Wick 310 may also include, in some implementations, a composite structure. Wick 130 may have a higher thermal resistance, but better capillary pumping action, than boiling structure 130.

[0024] The foregoing description of one or more implementations consistent with the principles of the invention provides illustration and description, but is not intended to be exhaustive or to limit the claimed invention to the precise form disclosed. Modifications and variations are possible in light of the above teachings or may be acquired from practice of the invention.

[0025] For example, although heat pipe 100 herein has been described by itself, other cooling techniques also may optionally be used. For example, a cooling fan (or other forced-air cooling device) may or may not be used in conjunction with heat pipe 100 within a mobile computer or other electronic device.

[0026] Further, although certain example numerical ranges are given above for lengths, sizes, and values, these ranges are purely exemplary and may vary according to design needs. The

values given may vary, for example, 10-30% above and below the respective endpoints of the ranges given above.

[0027] No element, act, or instruction used in the description of the present application should be construed as critical or essential to the invention unless explicitly described as such. Also, as used herein, the article "a" is intended to include one or more items. Where only one item is intended, the term "one" or similar language is used. Variations and modifications may be made to the above-described implementation(s) of the claimed invention without departing substantially from the spirit and principles of the invention. All such modifications and variations are intended to be included herein within the scope of this disclosure and protected by the following claims.